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EPIDEMIOLOGIC DIAGNOSIS AND MANAGEMENT OF TYPHOID FEVER.*

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The purpose of this contribution is to present particularly the results of application of all available measures in an epidemic of typhoid fever; however, the diagnosis of the source and the associated studies which were made in this instance are of sufficient importance to warrant their presentation.

In accordance with the instructions of Dr. Samuel G. Dixon, Commissioner of Health, the writer proceeded to Troy, Bradford County, Pennsylvania, on October 12, 1912, in order to investigate the reported prevalence of the disease in question.

The Borough is a very old one and the citizens are, for the most part, retired agriculturists, dairymen or employees of three principal industries, the Troy Engine and Machine Company, the Troy Tanning Company, and the Troy Creamery Company. From a financial point, the Borough is considered the most thriving municipality in Bradford County. There are many wealthy residents. The population has varied but little during a period of 30 years; in 1890 the United States Census Reports recorded a population of 1,307; in 1900, 1,450; and in 1910, 1,288. The census made by inspectors of the State Department of Health during October, 1912, recorded a population of 1,343.

This Borough has previously been practically free from typhoid fever; one case was reported during 1911 and none during the months of 1912 prior to the epidemic. The township of Troy surrounds the Borough and the major portion of the watershed of the West Branch of Sugar Creek. During a period of 10 years there have been but two cases of typhoid fever reported from premises located on the West Branch of Sugar Creek and its tributaries. The first case occurred during 1904, and the patient has not resided on the watershed during the past three or four years. The second

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Uncooked vegetables or fruits within 30 days? Yes. No. Where grown?.....
 Name of dealer supplying ice.....Where harvested?.....
 Drinking cups, table ware, etc. boiled? Yes. No. Sewer connection. Yes. No.
 Privy? Yes. No.
 How are stools and urine disinfected?.....
 Disposal of stools and urine. Sewer. Privy. Cesspool. Buried.....
 Are stools and urine at any time exposed to insects, flies, etc.? Yes. No.
 Garbage disposal.....Kitchen waste.....Wash water.....
 Have they unslaked or chlorinated lime? Yes. No. What other disinfectants?..

 How and where used?.....
 Animals—Cats, Dogs, Goats, Birds, Chickens, Rats, Mice?.....
 Circular left.....House placarded.....
 Abatement notices.....What for?.....
 Remarks:

Data obtained by:

The census is made by trained inspectors, who report daily to the officer in charge and dictate the details of each case to an inspection clerk. From the latter's records the tabulated results are compiled.

EPIDEMIOLOGY.

The results as tabulated at the end of the epidemic conform to the findings following the census of 41 cases made on October 12 and 13 by five special inspectors and one sanitary inspector. The compiled tables contributed certain interesting facts to the diagnosis of an epidemic; for the sake of brevity, only the general results are presented.

There were 229 cases of typhoid fever which were infected in the Borough of Troy, 225 of which were primary and 4 secondary cases. The careful census of the town gave a total tabulation of 1,343 persons residing in 367 premises. Thirty-two cases were located in other health jurisdictions. Of these, 122 or 33.24 per cent housed persons ill with the disease, the distribution being as follows:

72	houses	with	1	case
32	"	"	2	cases
9	"	"	3	"
3	"	"	4	"
2	"	"	5	"
1	house	"	6	"

The tabulation of the age periods is as follows:

Years of Age	Cases	Percentage
0-5.....	13	5.6
5-10.....	36	15.28
10-30.....	99	43.24
30-40.....	34	14.84
40-50.....	23	10.04
50-60.....	15	6.55
60-70.....	9	3.93

The study of this table brings out certain interesting factors in relation to susceptibility. The large percentage of cases between the 10th and 30th years indicates that the source of transmission was water-borne, but the total range of susceptibility suggests some other factor, common to all, which is not usually found in water-borne epidemics. In practically all water-borne epidemics in Pennsylvania, from 60 per cent to 70 per cent and occasionally over 80 per cent of the cases have been between 10 or 15 and 30 years of age. In milk- or ice-cream-borne epidemics, the predominant age is well below 15 years. As will be shown, these two possible agents were excluded. The disease was fairly evenly distributed between males and females, 127 of the former and 102 of the latter being reported. Occupation was not a factor, as every type of employment was represented among those sick. The most probable factor is that the disease has not been endemic in that region, and the residents have not had that "accustomance" to repeated minimal doses of the toxins of the specific microorganisms.

This theory has some confirmation in the total morbidity which amounted to 17 per cent. In no other reported epidemic has there occurred so high a relative morbidity. The epidemic at Plymouth, Luzerne County, Pennsylvania, during 1895, showed a morbidity of about 11 per cent; that in Butler, Butler County, Pennsylvania, during 1903-4 was about 7 per cent of the total population. The degree of pollution of the water-supply would not account for the high morbidity; if it were possible to draw "a curve of pollution," the latter would not, though marked, present the excessive pollution curve shown in the Coatesville epidemic during February, 1912, in which the morbidity was 2 per cent of those exposed. Hence, we believe that these factors are illustrations of the absence of an acquired tolerance or immunity.

The 229 cases were supplied with milk from 66 different and 1 undetermined sources. Thirty-nine were supplied by their own cows and 189 by various dealers. There were 5 principal milk routes, only one of which proved important enough to mention. This man supplied 157 families, in which there occurred 87 cases of typhoid fever. His wife had suffered with the disease about 20 years previously, and prior to the epidemic period had washed the bottles and other utensils. Careful and repeated examination of the feces and urine failed to recover any pathogenic member of the typho-colon group. At some time within the incubation period, 108 cases had used ice cream. In 15 cases it was "home made" from milk and cream obtained from cows maintained on the premises. In 93 cases it was obtained from 10 local dealers; 55 ate ice cream from 3 principal dealers who purchased their supply from a manufacturer in Elmira. An investigation of the latter's plant proved negative.

Twenty-five, or 10.91 per cent, used shell fish, purchased at 6 different stores or restaurants; 3 of them obtained a supply from the same dealer, but the small number made it unnecessary to follow out the bacteriological examinations.

Ice was readily excluded from consideration as it was used by but few families. The supply came through one dealer from the West Branch of Sugar Creek below the municipal water collecting system and had been harvested during January and February, 1912. Bacteriological analysis of this ice gave negative results for *B. coli* and the highest total count was 17 per 1 c.c. However, specimens of water collected from the pond during December, 1912, gave the following counts:

	Total per c.c.	<i>B. coli</i> per c.c.
North End	2,500	320
South End	2,000	400

Of the patients, 226 had used the municipal water; 3 had not used that water, but were nurses who were secondary cases; 168, or 74 per cent, used no other water; 51, or 22.5 per cent, used well or spring supplies in addition to the Borough supply, but studies of physical environment and bacteriological analyses excluded them as transmissive agents; 10 obtained water from neighboring

municipal supplies to which no cases of the disease have been traced.

An analysis of the conditions relative to the supply shows that it was designed to be obtained from a system of springs (Fig. 1), the water of which was piped to a common point known as the upper collecting reservoir and to which point was also collected the ground waters from various points in a natural gravel formation, all being



FIG. 2.—The upper collection reservoir, 35 feet distant from creek bank. Piping of drilled well noted in background.

in a vale through which flowed the West Branch of Sugar Creek. These sources have been purchased by the Borough, and the three acres of land were known as the "Spring Lot." This three-acre tract is located one and one-half miles west of the Borough, and the water is delivered by gravity to two distributing reservoirs situated at the west edge of the Borough; at this point an auxiliary supply was obtained from a drilled well. A small low-surface district in the south end of the town furnished a small supply from the spring owned by the Pennsylvania Railroad Company about a mile



MAP 2.—Showing distribution of the fifty families.



MAP 2.—Showing distribution of the fifty families.

southeast of the Borough and delivered to and connected with the first system by gravity.

At the Spring Lot there were six shallow springs and two 8-inch diameter, flowing, drilled wells, 100 and 194 feet deep respectively. The water was collected in a system of open-joint tile pipes and conveyed to a common point called the upper reservoir (Fig. 2), from which it passed by gravity through an 8-inch main to a distributing



FIG. 3.—West Branch of Sugar Creek. Uranine, placed in a pocket near the large stones in the foreground, appeared in the reservoir within 33 seconds. The perforated barrel is located in the creek bed to the extreme left.

reservoir at the edge of the Borough. In addition, there were two creek intakes at the Spring Lot: the one a perforated barrel sunk into the bed of the stream (Fig. 3), covered with flag stone, while the other was an underground concrete diverting wall leading under the bed of the stream from a small collecting chamber located in a meadow on the opposite side of the creek. The intended purpose of this wall was to intercept the ground waters and to deliver them to the upper collecting reservoir. Whether intentionally or otherwise, direct communication was made with the creek.

The sodium salt of fluorescin (uranine) placed in the creek at this point appeared in the upper reservoir (35 feet distant) within a period of 33 seconds, while the same dye, when placed in the perforated barrel, appeared in the lower collecting reservoir (550 feet distant) within 20 minutes.

The normal flow from the Spring Lot, with the creek waters shut out, amounted to approximately 80,000 gallons in 24 hours. This

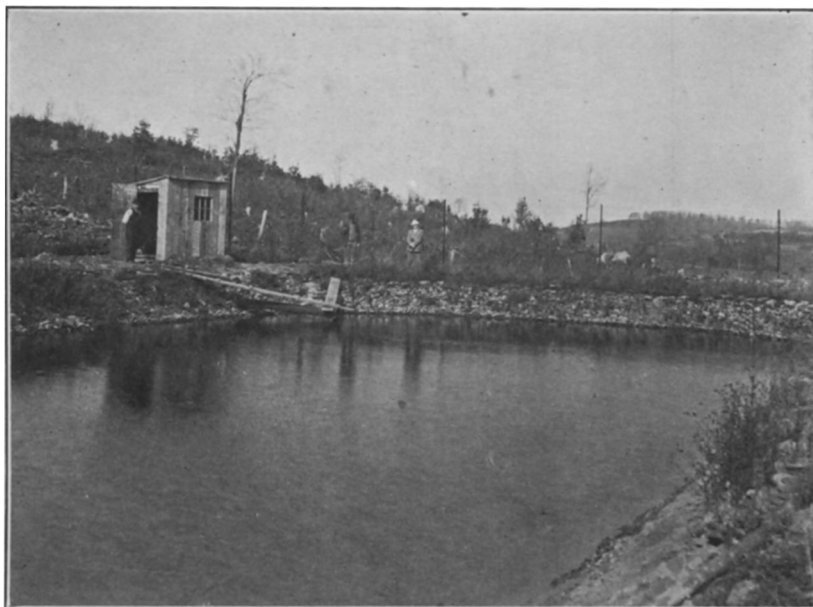


FIG. 4.—Open distributing reservoir and discharge pipe from collection system in the foreground. The pump station for drilled well at this point and the covered reservoir are shown in the background.

was markedly increased by rises, thus indicating the surface nature of the supply. The drilled well at the distributing reservoirs was 4 inches in diameter and 265 feet deep; it was used as an auxiliary supply, pumped by air and had a capacity of about 50,000 gallons during the daily pumpage. The two distributing reservoirs (Figs. 4 and 5), located at the west edge of the Borough had a total storage capacity of 200,000 gallons. All of the water, except from the Pennsylvania Railroad supply, passes through these reservoirs.

Extensive repairs and alterations had been made, the work

beginning late in June and ending on or about September 10. During this period 14 men were employed more or less constantly, and the hygiene at this time was open to suspicion. However, none had previously suffered an attack of typhoid fever, and the history of the other abdominal disturbances was considered too vague to be reliable.

During the winter of 1911-12, there were 4 cases of typhoid



FIG. 5.—The open distributing reservoir, the discharge pipe from the collecting system, and the temporary building erected to house a temporary hypochlorite of lime treatment plant. All water was treated at this point.

fever in one family who lived on the banks of the West Branch of Sugar Creek about 1 mile below the municipal source of water-supply. One W.S., employed on that farm, was taken ill late in the month of February, 1912. His onset is officially recorded as March 4, on which date he returned to the home of his father who lived on a small tributary to the West Branch of Sugar Creek, known as Spring Run. This patient was placed under quarantine immediately upon arrival; a trench was dug for the disposal of the excreta, all of which were thoroughly disinfected with fresh unslaked lime prior to burial in the trench. The trench was located adjacent

to the privy vault, which was about 100 feet distant from and about 50 feet in elevation above Spring Run. There is no evidence that storm water, except under extraordinary conditions, would cause drainage from these points into the stream. However, W.S. worked in harvest fields through which Spring Run and a portion of the West Branch of Sugar Creek flow; during that period and subsequently, he states that at times discharges were deposited in the fields adjacent to the stream. As this was the only authentic case of typhoid fever occurring on the watershed, specimens of feces and urine were collected on October 15, 1912, which, after careful examination, proved to be negative. On November 12 additional specimens were procured, and from the feces, *B. typhosus* was identified by all the required iso-murtoric tests. The type recovered was subsequently used (because of its agglutinability) to study the sera of certain cases from the same epidemic.

In addition to the pollution from this source, there were 7 privies, 1 cesspool, and 27 miscellaneous sources of pollution, including pig-pens, barnyards, and kitchen wastes. There was a population of 35 in an area of 3 square miles on the watershed above the point of collection of the Borough water-supply.

The history of weather conditions, according to unreported observations, indicates that there was an unusual precipitation during the summer, particularly in association with severe electric storms. The West Branch of Sugar Creek is subject to quick rises and rapid falls, as is usual in deforested regions. It was not possible to secure observations made in or near the Borough, and the records from the United States Weather Bureau Service, taken at Wellsboro, Tioga County, which is 28 miles west; at Elmira, N.Y., which is 25 miles north; at Towanda, Bradford County, which is 22 miles east, and at Williamsport, Lycoming County, which is 50 miles south, show a rather remarkable correlation in the dates and amounts of precipitation. The observations which bore a direct relation to the incidence of the epidemic are as follows:

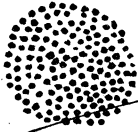
	September 15-16	September 22-25
Wellsboro.....	1.59 in.	1.96 in.
Elmira.....	1.05 in.	2.38 in.
Towanda.....	0.45 in.(4hrs.)	2.55 in.
Williamsport.....	0.24 in.	2.38 in.

No. 1

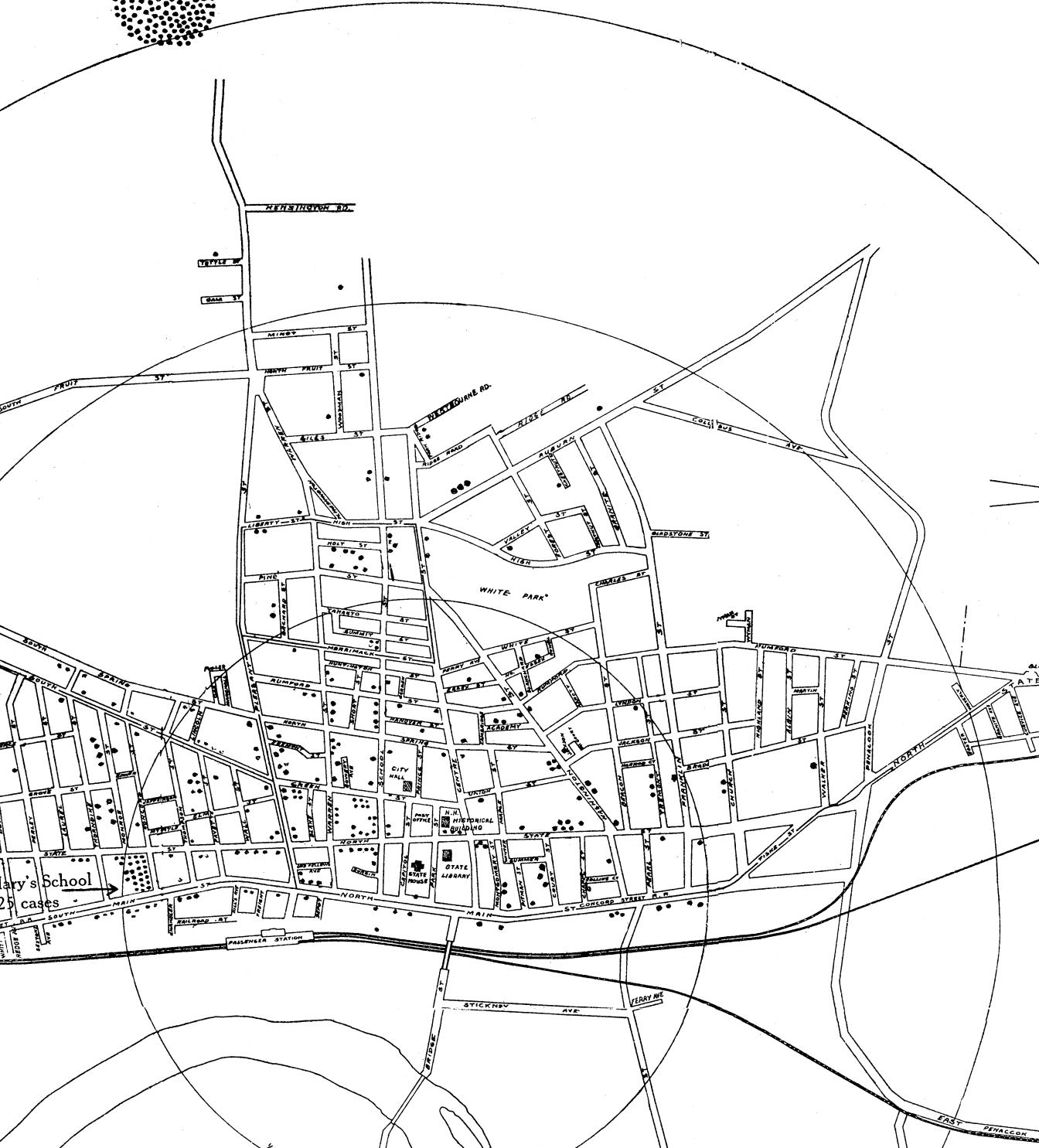
Map showing distribution of 472 cases of "Septic Sore Throat,"
in Concord, N.H., Jan. 1st to Feb. 15th 1912.



CONCORD



St. Paul's School
121 cases



This is a detailed black and white map of a section of Portland, Maine. The map shows a grid of streets, including Valley St, White Park, Stickney Ave, and the River. Key landmarks include Garden Hill Cemetery and Garden Cemetery. A compass rose indicates the magnetic orientation. The map is oriented with North at the top.

Streets shown include: VALLEY ST, WHITE PARK, STICKNEY AVE, GARDEN HILL CEMETERY, GARDEN CEMETERY, and the RIVER. Other streets visible are: VALLEY ST, WHITE PARK, STICKNEY AVE, GARDEN HILL CEMETERY, GARDEN CEMETERY, and the RIVER.

Compass rose: MAGNETIC







Representative analysis of specimens obtained from various portions of the system are noted in the following table:

	Total Bacteria per c.c.	B. coli per c.c.
Raw water, W. Branch Sugar Creek	240	2
Inlet Pipe, Upper Collecting Basin, Spring Lot.....	10,000	I
Inlet Pipe, Lower Collecting Basin, Spring Lot.....	200	I
Lower Collecting Basin	100	I
Inlet, Lower Collecting Basins	720	2
Open Reservoir (Distributing)	60	2
Covered Reservoir (Distributing)	9,500	14
Up-Stream Drilled Well, Spring Lot.....	300	O
Down-Stream, " " " "	200	O
Spring No. I, Spring Lot.....	40	O
Spring No. 2, Spring Lot.....	100	O
Spring No. 3, Spring Lot.....	O	O
Spring No. 4, Spring Lot.....	35	O
Drilled Well at Open Reservoir (Distributing)	20	O
P.R.R., Parson's or Cases' Spring.....	10,000	24
Taps:		
Elmira Street	2,500	I
Canton "	1,500	I
Canton "	600	O
Troy Creamery	50,000	O
Penn. R.R. Station.....	12,000	O
Lower Elmira Street.....	24,000	O

It is observed that the springs and drilled well waters were uniformly negative, while all portions of the collecting and distributing system show the evidence of pollution.

DIAGNOSIS.

The epidemiologic diagnosis was based on the explosive character of the outbreak, the facts relative to the changes in the water system and the exclusion of milk, foods, ice, and ice cream as being improbable means of transmission. The individual diagnosis was in many cases more difficult to establish, especially early in the epidemic when a large percentage of the cases were in the prodromal stage of the disease. On the date of our arrival, physicians were not willing to report them as cases of typhoid fever to the local Board of Health because of the atypical onsets, and to a certain extent, atypical clinical courses. It was possible to study in consultation with the local physicians, a large proportion of the patients. From experience in previous epidemics in Pennsylvania it was advised that the sera of all atypical cases should be studied in relation to the following microorganisms: *B. typhosus*, *B. paratyphosus* A and B, *B. para-coli*, *B. enteritidis* (Gaertner), and *B. suisepticus*. This work was performed by the State Laboratories without expense to the physicians or patient. A constantly negative agglutination was obtained with *B. suisepticus*. In 47 cases the titer limit was studied in relation to each of the above microorganisms. Sixteen of these cases showed the presence of agglutinins for the *B. enteritidis* (Gaertner) and were negative to all other microorganisms throughout the course of illness in which so studied.

It is interesting in this relation to note the fact that the only pathogenic member of the typho-colon series which was recovered from the water-supplies was a form identical in its biochemical and iso-murtoric behavior with the original Gaertner form of *B. enteritidis*; this microorganism was recovered from samples of water collected for the purpose from the distributing reservoirs. The sera of the 16 patients referred to agglutinated this microorganism in dilutions of 1-50 at the end of one hour. For purposes of sanitary supervision, these 16 cases have been included in the total of 229.

MORTALITY.

The mortality in this epidemic was 19, or 8.29 per cent. This is an unusually low mortality as in similar water-borne epidemics

in Pennsylvania the mortality usually ranges from 10 per cent to 14 per cent.

In other words, this epidemic presents a high case morbidity with a low case mortality. The first reasonable suggestion is that the particular strain of *B. typhosus* was of reduced virulence. Had the low mortality depended entirely upon diluted pollution, it is probable that the relative morbidity would have been lower, despite the apparent susceptibility of those exposed. While definite conclusions cannot be made, it is suggested that the particular bacillus, having passed 6 to 8 months in a host who had developed resistance to its pathogenic power, would undergo certain modifications in virulence.

TREATMENT.

Having established a tentative diagnosis on the day of arrival, measures, under the supervision of Mr. H. E. Moses, sanitary engineer of the State Department of Health, were taken to eliminate the infected waters, to furnish sufficient supply for fire protection and to establish a treatment plant. In order to accomplish this, it was necessary to cut out from service the Pennsylvania Railroad spring supply as well as the spring supply polluted by the creek waters. Because of the connection at the "Spring Lot" it was possible to continue the use of water from the springs and the drilled wells, and to this was added the supply from the drilled well at the distributing reservoirs.

The water in both reservoirs was treated with copper sulfate solution in the proportion of two parts per million gallons. This treatment was continued over a period of nearly two days, by which time a temporary plant for treating with hypochlorite of lime was put into service (Fig. 4). The distributing reservoirs were disinfected on October 16 and again on October 19, with copper sulfate solution and subsequently washed out with the treated water. At the same time the street mains were flushed, all dead ends and taps being opened until the water showed the presence of hypochlorite of lime at all points. The use of hypochlorite of lime has been continued to this date without the occurrence of any cases and pending the submission of plans by the engineer employed by the Borough.

After an examination of a large number of cases on the afternoon of October 13, the local Board of Health and physicians were advised to use antityphoid vaccine. This suggestion was immediately followed, and those who were not inoculated by their family physician were offered free vaccination at stations established by the Borough authorities. Physicians from neighboring points offered their services free of charge, and in co-operation with the local physicians and myself, 761 persons, or 56.66 per cent of the total population exposed to the infection, received the vaccine. Of these, 8, or 1 per cent, received inoculations conforming to the formula used in the United States Army; that is:

	Syringe A	Syringe B	Syringe C
<i>B. typhosus</i>	500	1,000	1,000 million

753, or 99 per cent received a trivalent vaccine in three doses, containing the following:

	Syringe A	Syringe B	Syringe C
<i>B. typhosus</i>	500	1,000	1,000 million
<i>B. paratyphosus</i> A.....	250	500	500 "
<i>B. paratyphosus</i> B.....	250	500	500 "

The inoculations were made at intervals of from eight to ten days.

A tabulation of the results is as follows:

Total number of persons exposed.....	1,343
" " " " vaccinated.....	761 or 56.66 per cent
" " " " unvaccinated.....	582 or 43.32 per cent

The study of the use of vaccine in relation to onsets and morbidity is as follows:

Total number of cases.....	229
Onsets prior to use of vaccine.....	127 or 55.46 per cent
" after the " " "	102 or 44.54 per cent

The morbidity in relation to onsets and use of vaccine shows that 65, or 63.72 per cent, were not inoculated, while 37, or 36.27 per cent, were inoculated.

The morbidity in relation to the total number of persons vaccinated and unvaccinated shows the following:

No. of persons vaccinated.....	761
" " these developing typhoid fever.....	37 or 4.86 per cent
" " persons not vaccinated.....	582
" " these developing typhoid fever.....	65 or 11.16 per cent

It will be noted from this table that 102 persons developed the onset of the disease subsequent to inoculation, and that 37, or 36 per cent, of the vaccinated and 65, or 64 per cent, of the unvaccinated developed the disease. It will also be noted that the infection of the water occurred (so far as it is possible to determine) prior to September 25, and was probably more or less continuously infected to October 7. The water was definitely disinfected on October 14, and it is reasonable to conclude that the incubation period of all persons exposed continued to about November 4. Hence, we have reason to believe that the use of antityphoid vaccine was an important factor in preventing the occurrence of a number of cases, and we are fortified in this opinion from the fact that this community, as has been noted above, has been a typhoid-free community, that the residents are of a sedentary rather than of an itinerant type, and have probably had less opportunity for gaining immunity through continued exposure in other places. Those who have traveled much traveled under conditions which made it improbable that they should be exposed to or develop an infection of this type.

Through the active co-operation of the local physicians and the ready acquiescence of every resident of the Borough, it was possible to establish prompt quarantine with isolation of every patient. Concurrent disinfection of all discharges, of all bed linens and clothing, of all utensils and the attendants' hands was efficiently carried out. Arrangements were made with the laundry in the Borough not to accept clothing or bed linens coming from known infected homes unless such pieces of laundry were first boiled and disinfected. All milk routes were placed under sanitary supervision, and no containers were permitted to be removed from premises in which the disease existed. Warning placards and circulars were distributed throughout the town, instructing the residents not to drink water which had not been boiled for at least 30 minutes. The same type of warning was printed in the local newspapers and in newspapers issued from nearby points but having a circulation in the Borough.

On October 16 an emergency hospital was opened and placed under the direction of the supervising nurses of the State Depart-

ment of Health. The patients admitted to this institution were carefully selected with reference to their physical condition, to the possibility or impossibility of carrying out proper sanitation, or to the financial condition of the family. There was a total of 49 admissions to this institution with a mortality of 4, or 8 per cent. For the most part the patients admitted were seriously ill. All cases remained under the charge of their own physician. The hospital was closed on December 12, 1912.

Through local philanthropic agencies and particularly through the offices of the local visiting nurses' organization, an efficient district nurse service was inaugurated at once. This was particularly valuable in premises where assistance was needed and yet for various reasons the patients could not be admitted to the emergency hospital. The work of the district nurse made it possible for each patient to be visited two or three times each day and for a nurse to remain on duty for long periods of time in cases where there was need of prolonged assistance.

A relief committee was promptly organized to help those who needed assistance, and contributions were received from many points in Pennsylvania and New York. This organization was placed under the management of a sub-committee, a station was opened, and a careful record was kept of all monies and other supplies received and distributed. From the first day of its organization no assistance was rendered without a hasty but careful investigation as to the need for such assistance. There is no doubt but that the relief from mental distress on the part of many of the wage-earners contributed to their eventual recovery without serious complications, and it would appear from the experience in Troy that such sociologic measures are an important factor in limiting an epidemic and in reducing the mortality.

The features of the treatment of this epidemic were found in the opportunities to carry out all of the modern methods in detail. The diagnosis was established within 24 hours after arrival and was followed by prompt engineering interference. For the first time (so far recorded) an antityphoid vaccine was generally used during the height of an epidemic. Through local, individual, municipal, and county co-operation an Emergency Hospital and District

Nurse Service, sanitary and educational measures, and financial assistance were applied with minimum delay and maximum results. The number of secondary cases is often a measure of preventive work done; in Troy there were but 4 secondary cases, 3 of which were nurses; the 4th case was in all probability, and according to the evidence collected, infected by a temporary "carrier" in the same premises. The advisability of having physicians, nurses, and other contacts receive immunization by means of a vaccine is emphasized.